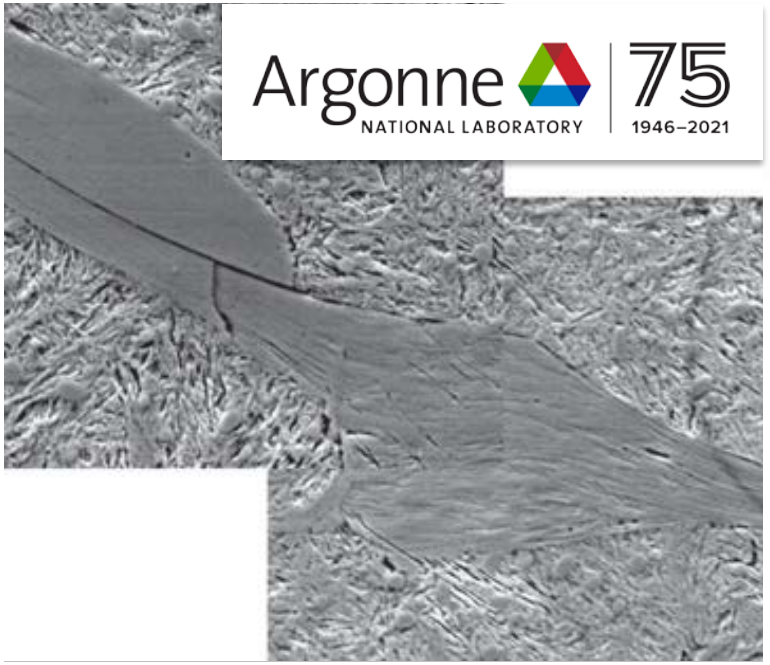
U.S. DEPARTMENT OF ENERGY

Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

2021 PROJECT PEER REVIEW

U.S. DEPARTMENT OF ENERGY
WIND ENERGY TECHNOLOGIES OFFICE

Argonne NATIONAL LABORATORY 75 1946–2021



T10 - Wind Turbine Drivetrain Reliability: Advanced Materials

Technology RD&T and Resource Characterization - Advanced Components, Reliability & Manufacturing

Aaron Greco

Argonne National Laboratory

August 3rd, 2021

FY21 Peer Review - Project Overview

Project Summary:

- Wind plant operations and maintenance (O&M) costs $12/megawatt hour and accounts for 25% to more than 35% of land-based and offshore wind levelized cost of energy. Pitch system, main bearing, and gearbox reliability are significant contributors to O&M costs. The predominant failure modes are not accounted for in design standards, not attributable to material deficiencies or manufacturing quality control, and independent of specific component suppliers. Characterizing failure modes, developing benchtop testing methods to replicate failures, and developing mitigation strategies will increase drivetrain reliability and turbine availability by reducing premature failures, unplanned maintenance and O&M costs.
- NREL, GE Renewable Energy

Project Objective(s) 2019-2020:

- Establish operational and material drivers for white-etching crack (WEC) bearing failures, develop benchtop testing methods to replicate WEC failures, quantify effectiveness of materials based mitigation

Overall Project Objectives (life of project):

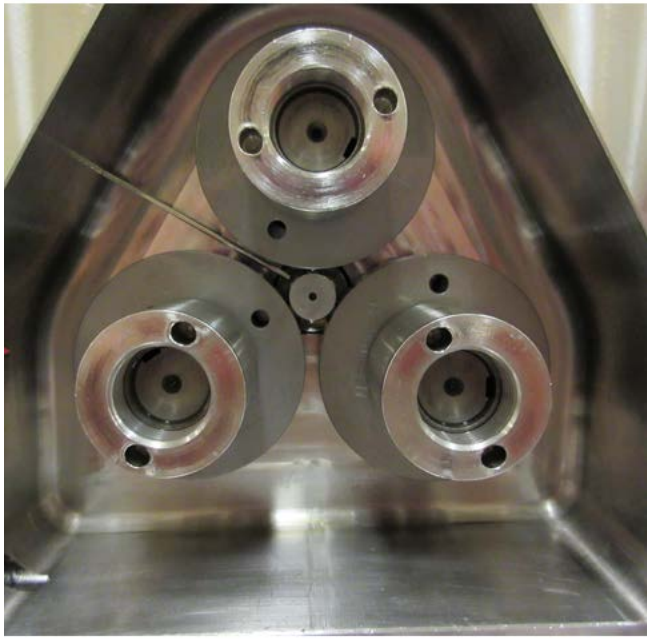
- Identify root cause of tribological failures, develop testing tools to accelerate identification and development of mitigation technologies

Project Start Year: FY18
Expected Completion Year: FY 21
Total expected duration: 3 years

FY19 - FY20 Budget: $1,725, 613

Key Project Personnel: Aaron Greco, Benjamin Gould

Key DOE Personnel: Mike Derby, Brad Ring, Lillie Ghobrial, and Tyler Christoffel



Project Impact

- **O&M costs are an important part of cost of energy!**
  - Account for 25% to 35% of levelized cost of energy (LCOE), representing $5B annual market in the United States
  - O&M costs are higher than expected; can account for 10% (land-based) to 50% (fixed offshore) of reduction in LCOE

Gearbox bearing WEC failure

Gould, Benjamin, and Aaron Greco. “The Influence of Sliding and Contact Severity on the Generation of White Etching Cracks.” doi:10.1007/s11249-015-0602-6.

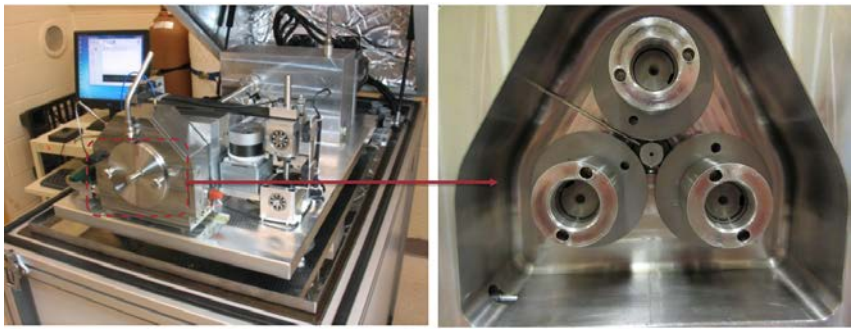
Program Performance – Scope, Schedule, Execution

- **Continued from prior peer review period** (FY15-18)
  - Established an operational threshold parameter for bearing WEC failures (related to frictional heat due to bearing sliding)
- **Merit-reviewed and was continued** (FY19-21)
  - Develop benchtop testing methods for replicating bearing WEC failure
  - Quantify the impact of stray electrical current on WEC failure
  - Evaluate the WEC performance of lubricant and coatings
  - Develop benchtop test methods for replicating main bearing and pitch bearing failures

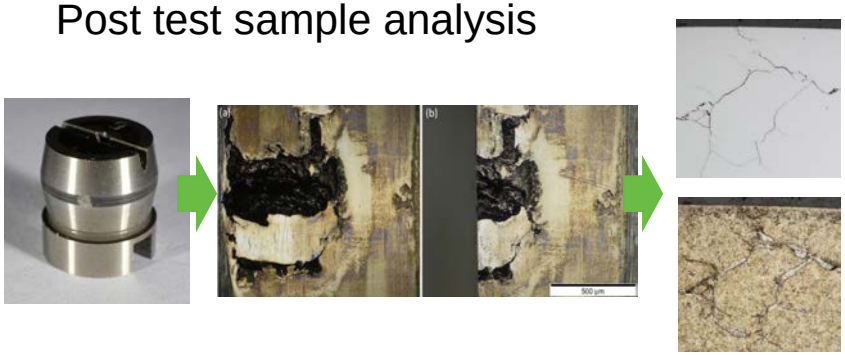
Program Performance – Accomplishments & Progress

- Developed new benchtop test methods for controlled replication of WEC failure
- Discovered linkage between slip at the contact and WEC formation
- Identified operational parameter: cumulative frictional heat energy, basis for NREL's Bearing Probability of Failure Model

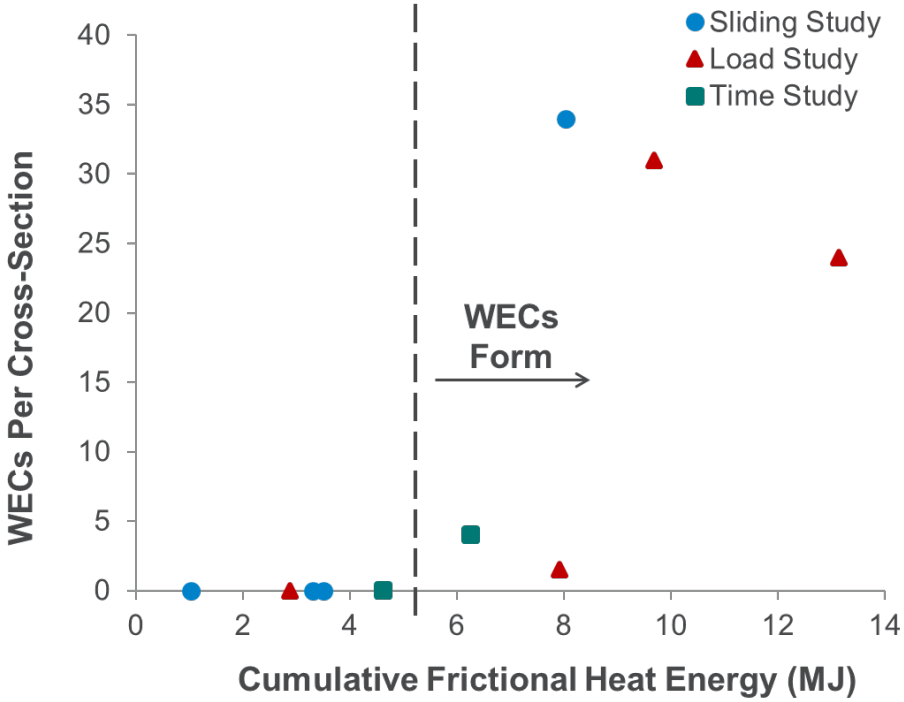
Benchtop test rig



Post test sample analysis



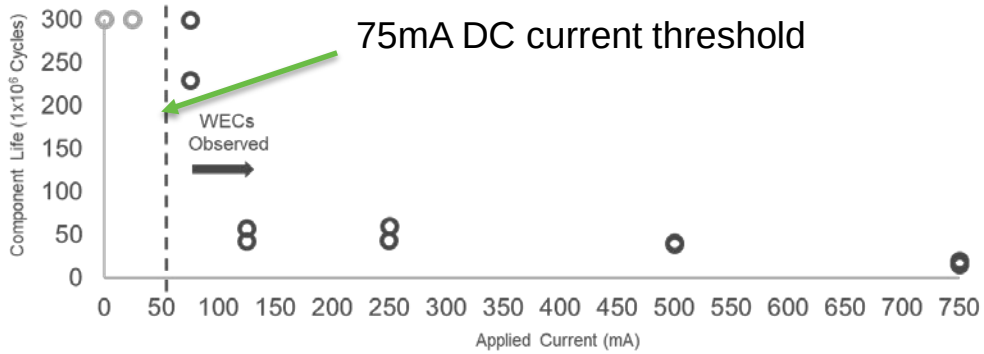
Friction energy threshold for WEC formation



Program Performance – Accomplishments & Progress

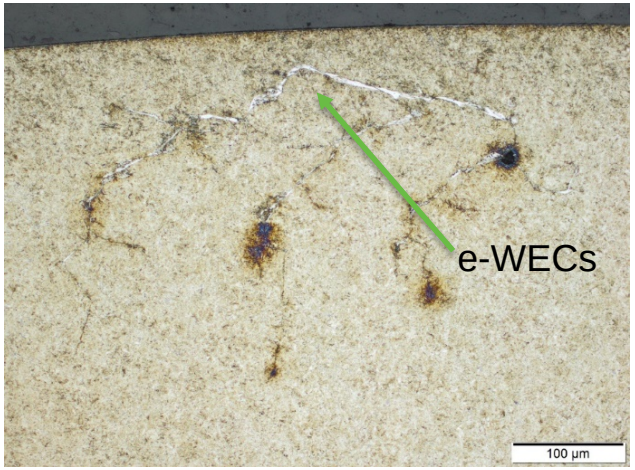
- Established impact of stray electrical current on WEC failure, e-WEC
- Evaluated lubricant chemistry and coating effect on e-WEC

Electric current threshold for WEC formation



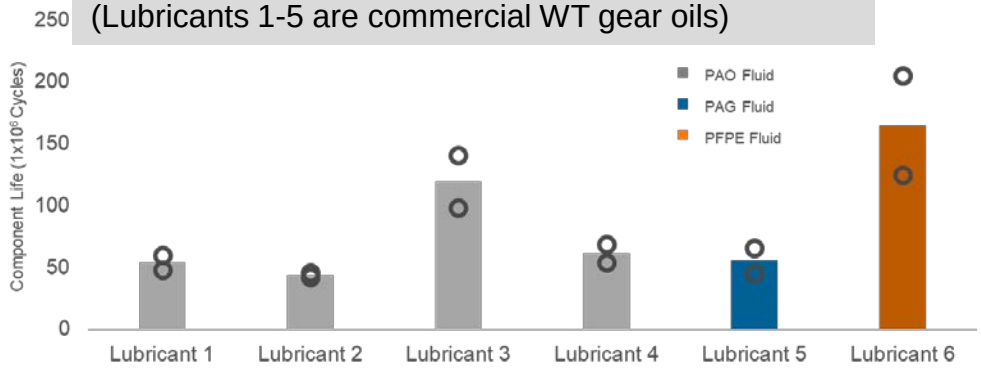
Gould, B., et al, *International Journal of Fatigue* 145 (April 1, 2021): 106078. https://doi.org/10.1016/j.ijfatigue.2020.106078.

Test sample cross section etched

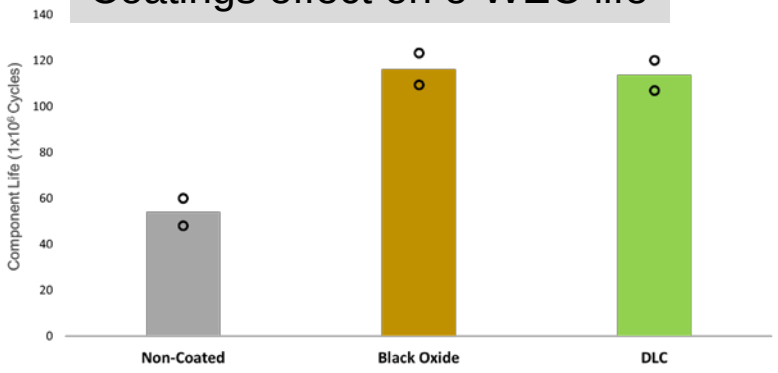


Lubricant chemistry effect on e-WEC life

(Lubricants 1-5 are commercial WT gear oils)

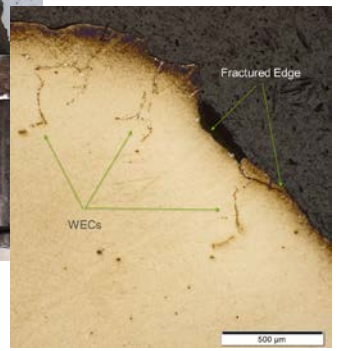


Coatings effect on e-WEC life



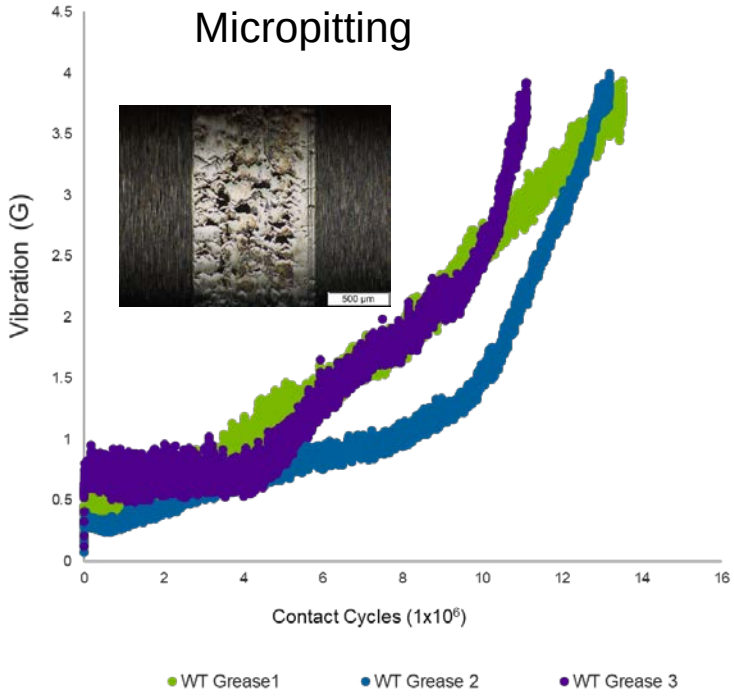
Program Performance – Accomplishments & Progress

- Identified failure modes impacting main bearings: micropitting wear and WECs
- Developed new benchtop testing methods to replicate both failure modes

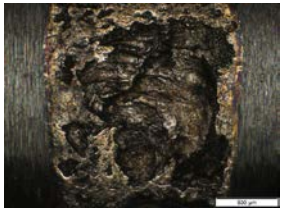


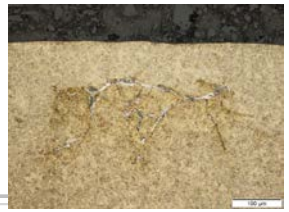
Main Bearing Benchtop Test Development

Micropitting



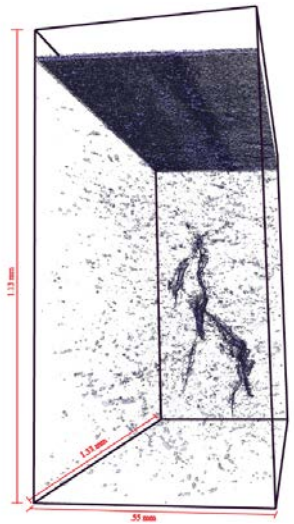
e-WEC macropitting

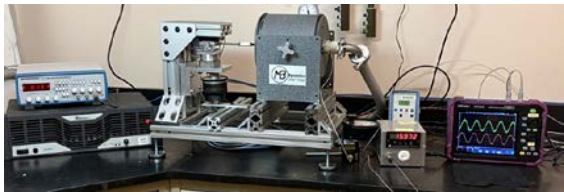




Project Performance - Upcoming Activities

- **GE Renewable Energy CRADA on WEC investigation (FY21-FY22)**
  - Perform benchtop evaluation of materials influence on WEC performance
  - Bearing steel cleanliness investigation using x-ray synchrotron source
- **Main Bearing testing (FY21 and beyond, subject to merit review)**
  - Establish operational parameters for micropitting wear, provide input for NREL model
  - Evaluate influence of grease and coatings on failures
- **Pitch Bearing reliability (FY21 and beyond, subject to merit review)**
  - Establish benchtop testing methods
  - Study operational parameters and influence of material choices
- **Advanced Materials Development (FY21 and beyond, subject to merit review)**
  - Coating development for mitigating eWEC failures
  - Advanced lubricant TCF project (FY22-FY24)





Stakeholder Engagement & Information Sharing

- **Collaborative meetings and workshops**
  - NREL hosted meeting
  - Argonne hosted Wind Turbine Tribology Seminar
- **Cooperative Research and Development Agreements**
  - GE Renewable Energy – WEC investigation
- **Publications and Data Release**
  - 6 journal articles, 8 conference presentations
  - Ongoing TCF project

Wind Turbine Tribology Seminar
Argonne, Oct 2019